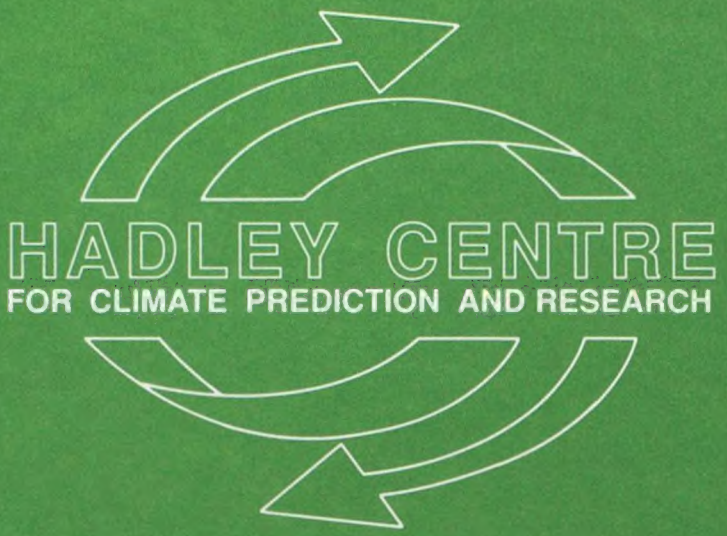

International Temperature Workshop

Boulder, Colorado, USA, 16 January 1992

Edited by D. E. Parker

CRTN 30

June 1992

CLIMATE
RESEARCH
TECHNICAL
NOTE

Hadley Centre
Meteorological Office
London Road
Bracknell
Berkshire RG12 2SY

CLIMATE RESEARCH TECHNICAL NOTE NO. 30

INTERNATIONAL TEMPERATURE WORKSHOP

BOULDER, COLORADO, USA, 16 JANUARY 1992

Edited by

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1. INTRODUCTION

An International Temperature Workshop was held on 16 January 1992, at the Clarion Hotel, Boulder, Colorado, USA. This report summarizes the proceedings of the workshop.

The workshop followed immediately after the International COADS Workshop which was held at the same location. The proceedings of the COADS Workshop are recorded in NOAA/ERL Special Publication No xx (1992). In view of the inclusion of papers on marine temperature data in the COADS Workshop, the International Temperature Workshop concentrated more, though not entirely, on land-based data. Therefore, to gain a more complete view of current research into temperature variations, both proceedings should be read.

The purpose of the Workshop was to share and encourage progress in collation, quality-control and analysis of surface and upper-air temperature data on both global and regional scales. The ultimate aim was the better knowledge and understanding of climatic mechanisms and variations, especially the influence of increasing greenhouse gases in the atmosphere.

Recommendations were as follows:

i. The quantity and timeliness of the monthly international exchange of CLIMAT data should be improved.

ii. Improved station documentation should include topographical maps and photographs in view of the sensitivity of minimum temperatures to topography. The more basic, traditionally exchanged information (eg latitude, longitude, elevation) should of course be obtained first.

iii. The WMO Reference Station Network, providing detailed reliable data, should be supported.

iv. We need to increase the international exchange of daily surface air temperature data, including maxima and minima.

v. There should be an international comparison of methods of quality-control and homogenization of surface air temperature data, analogous to the Working Group on Numerical Experimentation (WGNE) comparisons. Statistical techniques should be compared with those based on station-histories.

vi. Surface air temperature data should be assessed and analysed in the light of other types of observation.

vii. The interaction between marine (COADS, etc) and land-based research should be maintained.

viii. The development and verification of remote sensing should continue, but a homogenous Microwave Sounding Unit (MSU) record should be maintained.

ix. The reasons for the differences between surface and tropospheric temperature anomalies should be investigated using simple models.

x. Model-based reanalysis is a major target.

xi. There may be a case for an International Precipitation Workshop. In view of existing programs and associated conferences based on combinations of remotely-sensed with in-situ data (eg Global Precipitation Climatology Project (GPCP) and Tropical Rainfall Measurement Mission (TRMM)), the stress of the International Precipitation Workshop should be more on historical data.

The Editor is grateful to all who contributed to the workshop in any way, including Henry Diaz, Scott Woodruff and Julie McKie of NOAA/ERL who organised the practical arrangements for both this workshop and the preceding COADS Workshop.

Comparisons of MSU Temperature Retrievals with NMC Analyses

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In this study we compare two different data sources, NMC temperature analyses and Microwave Sounding Unit (MSU) brightness temperatures, to determine their usefulness, stability, and accuracy for climatic studies of global temperature patterns. The MSU data are derived from sensors flown on-board the NOAA TIROS series satellite. Channel 2 of the MSU has a weighting function that peaks around 500 mb, sensing the mean tropospheric temperature. Spencer et al (1990) have shown that this channel is very stable, and has a high signal to noise ratio. The NMC temperature analyses are produced as part of the Global Data Assimilation System (GDAS). Over land they are primarily based on atmospheric rawinsonde observations (RAOBS). Over the oceans, where few other data sources are available, the TIROS satellite instrument (which includes the MSU sensor) is a key data source.

Monthly means were calculated from the period 1982-90. Anomalies from these means were computed for the period 1979 - 1990. The GDAS mandatory levels are used to simulate the MSU-channel 2 weighting function (Hurrell and Trenberth, 1991), and the 2 sets of anomaly fields intercompared.

Fig. 1 shows the explained variance (R^2) between the MSU-channel 2 and the GDAS anomaly fields for the time period 1979 - 1990. Similar temperature patterns over the ocean areas, particularly at the mid to high latitudes, are partially an artifact of the MSU-channel 2 being used as a source in both data sets. However, similar anomaly patterns are also found over land where MSU data are not used in the NMC analysis. High correlations are generally found at the mid-to-high latitude land areas, where there is a high signal to noise ratio in the anomalies, and where the NMC analysis is based on a denser network of RAOB data. Low correlations over the tropical landmasses are a result of low signal to noise ratio and a much reduced network of RAOBS available for the NMC analysis. The lowest correlations occur over land areas with high surface elevations. Temporal changes in the NMC model orography and in algorithms used to interpolate temperatures over high terrain are responsible for these low correlations (Kalnay et al, 1990).

Problems over elevated surfaces are illustrated in Fig. 2, which compares the NMC analysis with channel 2 mean anomalies for 1987. The MSU-channels 2 mean anomalies for 1987 are a smooth field, with no contours exceeding 1.5 degrees. Thus, the positive "bulls-eyes" over all high terrain result from the NMC analysis (Fig. 2). These biases developed in the middle of 1986, in conjunction with NMC's adoption of envelope orography in the GDAS analysis.

Comparisons of month to month temperature changes remove biases associated with either data set. The January - February, 1989, anomaly differences, Fig. 3 and 4, demonstrate that both data sets depict temperature anomaly patterns once GDAS models biases are removed. The patterns are very similar, with a mean equal area squared correlation of 0.87. Clearly the MSU channel 2 temperature data can be used in conjunction with NMC analyses to monitor global temperature fluctuations.

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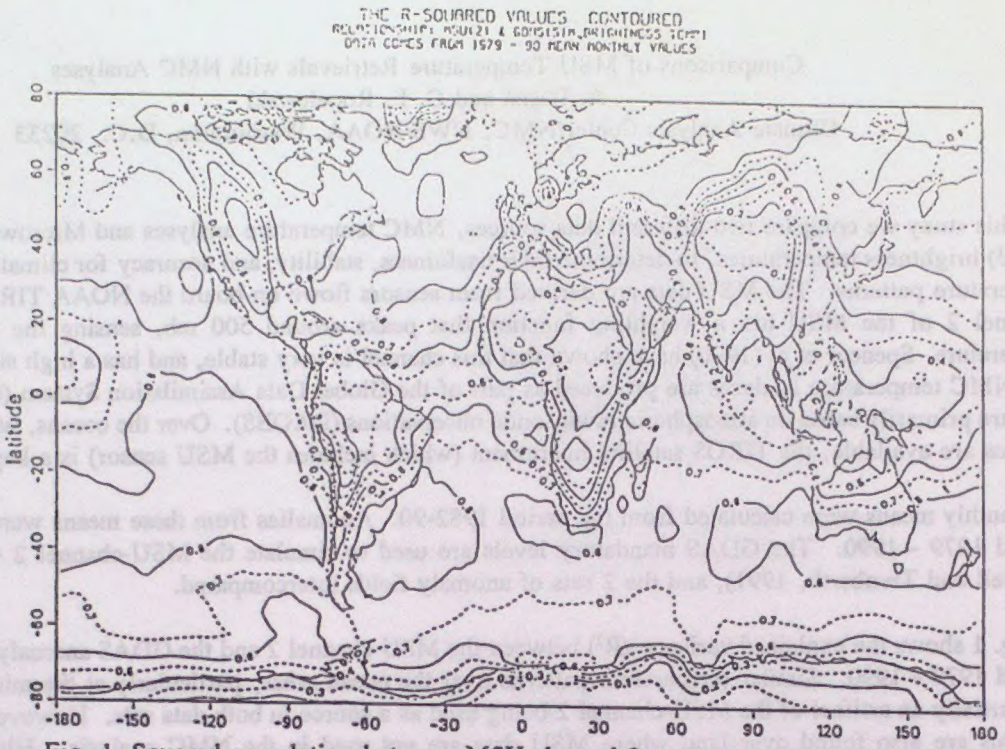

Fig. 1. Squared correlation between MSU-channel 2 temperature anomalies and simulated brightness temperature anomalies (derived from the mandi-tory levels of the NMC analysis).

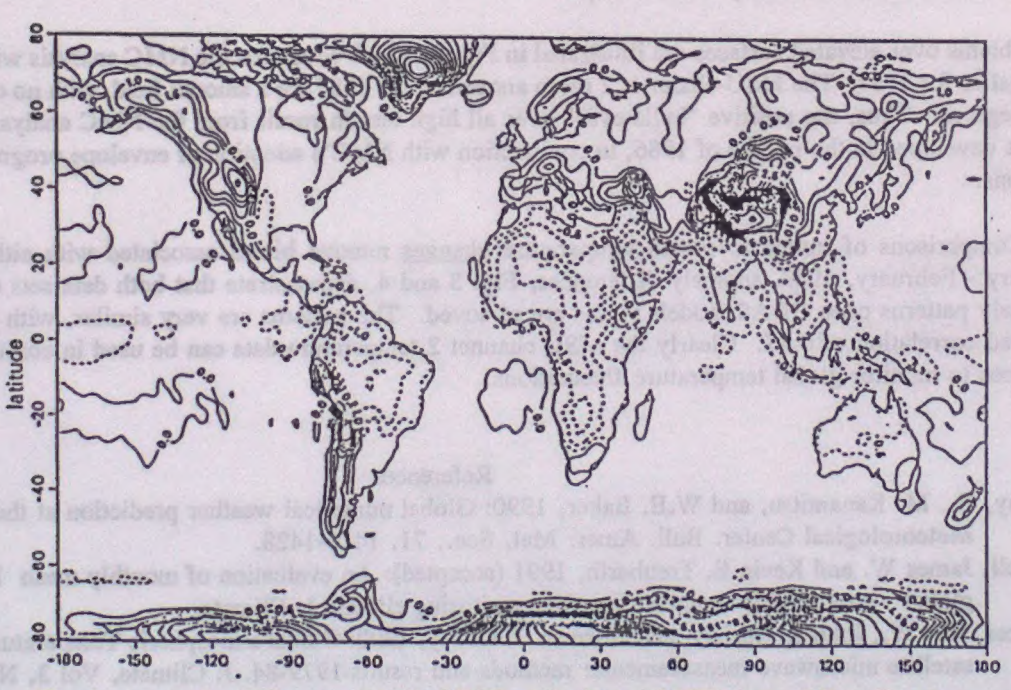

Fig. 2. Anomaly differences in the NMC analysis and MSU-channel 2. All areas of high elevations show large positive anomalies, resulting from temperature underestimates in the NMC analysis.

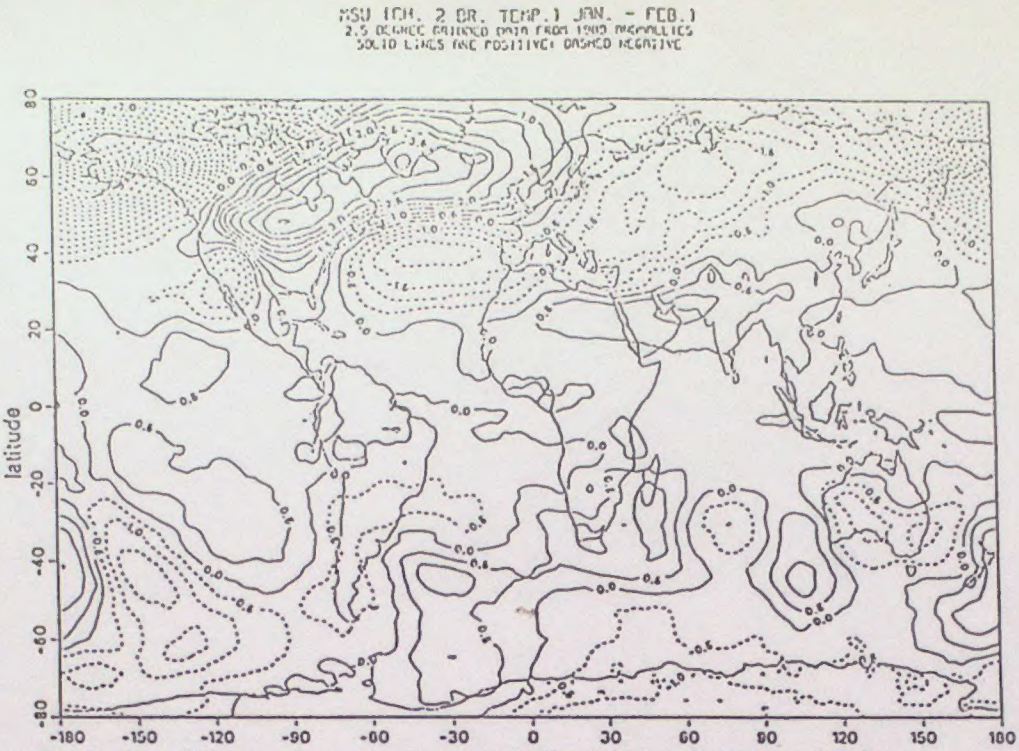

Fig. 3. The difference in temperature anomalies between January and February of 1989. The temperature anomalies were derived from the MSU-channel 2 sensor.

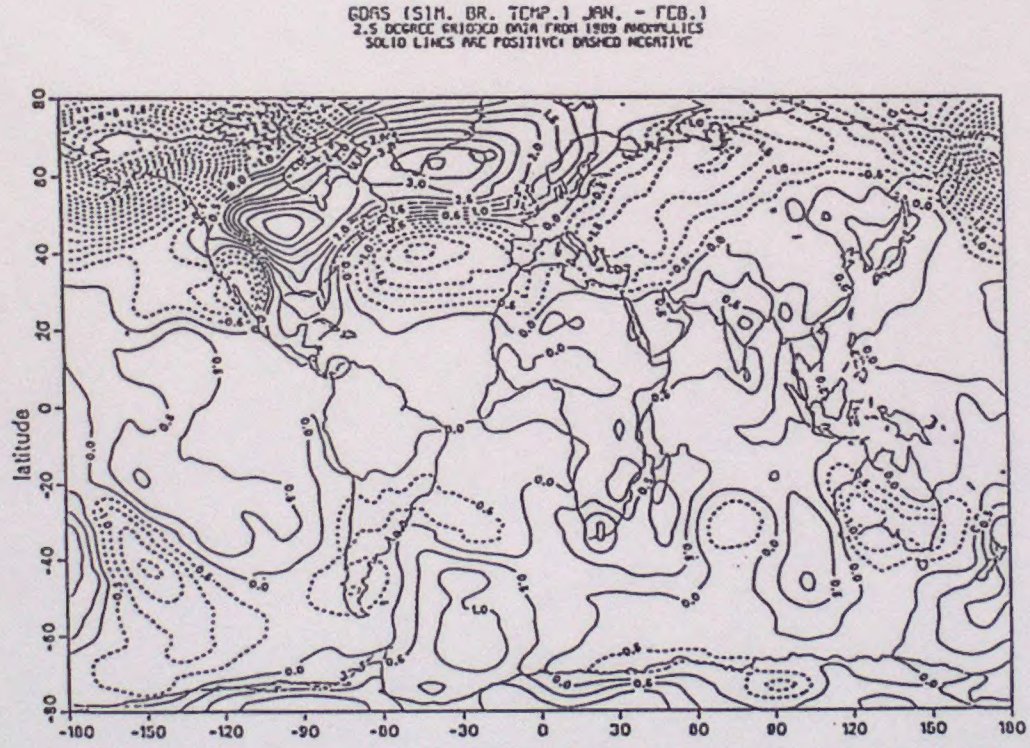

Fig. 4. The difference in temperature anomalies between January and February of 1989. The temperature anomalies were derived from the NMC analysis. During this time period no major model changes were introduced in the NMC analysis. The squared correlation between Fig.3 and Fig. 4. is 0.87.

International Temperature Workshop in Boulder on 16 January, 1992:

The creation of a Northern Atlantic climate data set, 'Atlantis'[1] - status and plans

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ABSTRACT

The factors determining the climate of NW Europe and particularly the Northern Atlantic area have attracted new attention in connection with the global warming issue. The tentative reduction of the area covered with snow/ice and the response of the ocean circulation in the North Atlantic region in a warmer world, particularly the behaviour of the Gulf Stream, are climate components of primary importance for the Nordic climate.

For the development and testing of parameterization schemes used with climate models it is of importance to have as good physical, observational based, data as possible for interpreting the natural processes and for verifying the relevance of the developed schemes. Also for statistical approaches to detect or characterize a climate change it is of importance to have access to high quality observational data sets.

Consequently, activities are going on within the Nordic and adjacent countries to create a climate data set covering a region within 50° N - 80° N and within 60° W to 40° E.

During the past 130 years a large amount of meteorological observations have been collected within this area. These data have in general before 1950 been stored in the observers' hand written diaries and part of these data have been published in yearly climatological bulletins.

Due to the fact that these data have hitherto generally not been accessible to computers they can be characterized as data buried at the bottom of the 'scientific ocean'. The question of global/regional climate change has shed new light on the historical climate data stocks and the Atlantis data set will during the next years successively rise to the 'surface' for future processing.

---

[1] The name 'Atlantis' is preferred instead of 'NACD' (the North Atlantic Climate Data set)

The cornerstones within the Nordic project are as follows:

- conversion of historical climatological information contained in publications/handwritten diaries to digital type. The common way for this conversion has been manual punching/conversion of data. In Sweden optical scanning of yearly climate publications based on ICR concepts (ICR= Intelligent Character Recognition) is now introduced for operational use. The highest priority is given to the following parameters: temperature, precipitation, air pressure, cloudiness. The list of parameters contains more than 20 items but it is uncertain whether it will be possible to realize the full list for financial reasons.

- test of the homogeneity of the data series. The probable homogeneity breaks obtained by the statistical approaches are checked by the information contained from the documentation in the meteorological archives based on inspection visits.

- transfer of the data to a data base.

- analysis of trends, variability etc of the parameters contained in the data series. This process has already started but the principal activity with this phase of the project will not be reached until about two years ahead, when the main part of the data hopefully has been digitized, checked for homogeneity and entered in a data base containing Atlantis.

The locations of the meteorological stations selected for Atlantis are illustrated by the preliminary map on the next page. Some of the stations might at a closer examination turn out to be inhomogeneous and can consequently be excluded from Atlantis in the future. The map below represents a 'minimum map' of stations and there are good prospects that a denser net of homogeneous data series will be contained in the final Atlantis.

ATLANTIS: Preliminary map of stations

DEVELOPMENTS IN AUSTRALASIAN SURFACE AND UPPER AIR TEMPERATURE DATA BASE

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1. Introduction.

This paper outlines the current status of historical temperature data sets (both surface and upper air) being compiled in the Australian / Southwest Pacific region.

2. Surface Temperature.

Two separate projects are currently underway within the Bureau of Meteorology to produce high quality surface temperature data sets. The first project, carried out by the Bureau of Meteorology Research Centre (BMRC) and the University of Melbourne Meteorology Department has as it main criterion for station selection a good quality long record. This data set is intended for research into climate change and interannual variability, and complements a similar data set for rainfall.

The National Climate Centre (NCC) archive contains approximately 1370 stations with some form of temperature record. Selecting only those stations that

- were in operation before 1910,
- are still in operation, and
- have not undergone major relocations,

reduces this number to 112. These criteria remove many of the Bureau staffed official stations which have been opened at, or moved to, airport sites since the 1940s. Also excluded are the long term capital city sites which may be subject to urbanisation effects.The spatial distribution of these stations, shown in Figure 1, is extremely uneven with major data voids in the central and northern sections of the continent. A number of long term records are available in this region: however, the sites have undergone considerable movement, eg the Darwin site was moved from the city to the airport in 1941.

The second project, undertaken by the National Climate Centre (NCC) is the Reference Climate Station Network, with selection criteria as defined by WMO. The length of record criterion is less stringent with a minimum requirement of 30 years. The distribution of the 85 'first choice' stations, shown in Figure 1, is therefore more uniform across the continent. Selection has also been based on the likelihood of the stations' continued operation, as one of the purposes of this data set is monitoring future climate change. Although these two projects have different aims and selection criteria, there are a number of stations common to both data sets, as is evident in Figure 1.

Long term temperature data sets have also been produced for New Zealand land stations (Salinger 1984) and selected Southwest Pacific Islands (Salinger 1992). The New Zealand land record commences with four stations during the 1860s, and seven representative stations have been used since the 1910s. The Southwest Pacific temperature records are generally from small islands or atolls and have much shorter periods of record.

3. Upper air temperature data.

The current Australian upper air network consists of 37 stations; 29 on the Australian mainland, 5 on remote offshore islands and 3 on the Antarctic coast. In addition there are a number of wind only observing stations.

The period of record is variable with the first observations at Darwin and Townsville in 1943. Approximately 20 stations were in operation by the International Geophysical Year (1957-8) when the observing time was standardised to 2300 UTC. Prior to this a number of different times had been used, with different change times at some stations. Almost all stations were operational by the mid 1960s, with some minor changes to the network in the late 1980s (new station at Gove, upgrade of Geraldton from wind only, and movement of radiosonde observations from Carnarvon to Learmonth). However further changes, mainly involving upgrading and movements in stations are planned (Thursday Island upgraded to radiosonde and moved to Weipa, Forrest moved to Eucla).

Daily data from all available stations, and including Honiara in the Solomon Islands, were manually quality controlled and archived by NCC until mid 1987. The process has now been largely automated and data are captured from the real-time system. Processing of data for the intervening period (mid 1987 to 1991) has commenced.

Monthly means of the radiosonde data for the period 1943 to 1955 were published as a Meteorological Summary (Bureau of Meteorology, 1958), and a climatology based on 1957 - 1975 data was published by Lee and Maher (1977). Monthly mean data from CLIMAT TEMP messages are available in the World Weather Records upper air climatology compiled by NCAR. CLIMAT TEMP messages have been archived by NCC only since 1985.

The current New Zealand network consists of six rawinsonde stations. Reorganisation during the late 1980s resulted in the movement of the Auckland site to Kaitaia, the closure of Christchurch and opening of a station at Paraparaumu, near Wellington. In addition New Zealand operate three sites in the Southwest Pacific; Tarawa, Funafuti and Raratonga, and archive data from Fiji.

The network of stations (excluding Tarawa, Funafuti and the Australian Antarctic sites) in the Australasian region for which data is available from Australian and New Zealand sources is shown in Figure 2.

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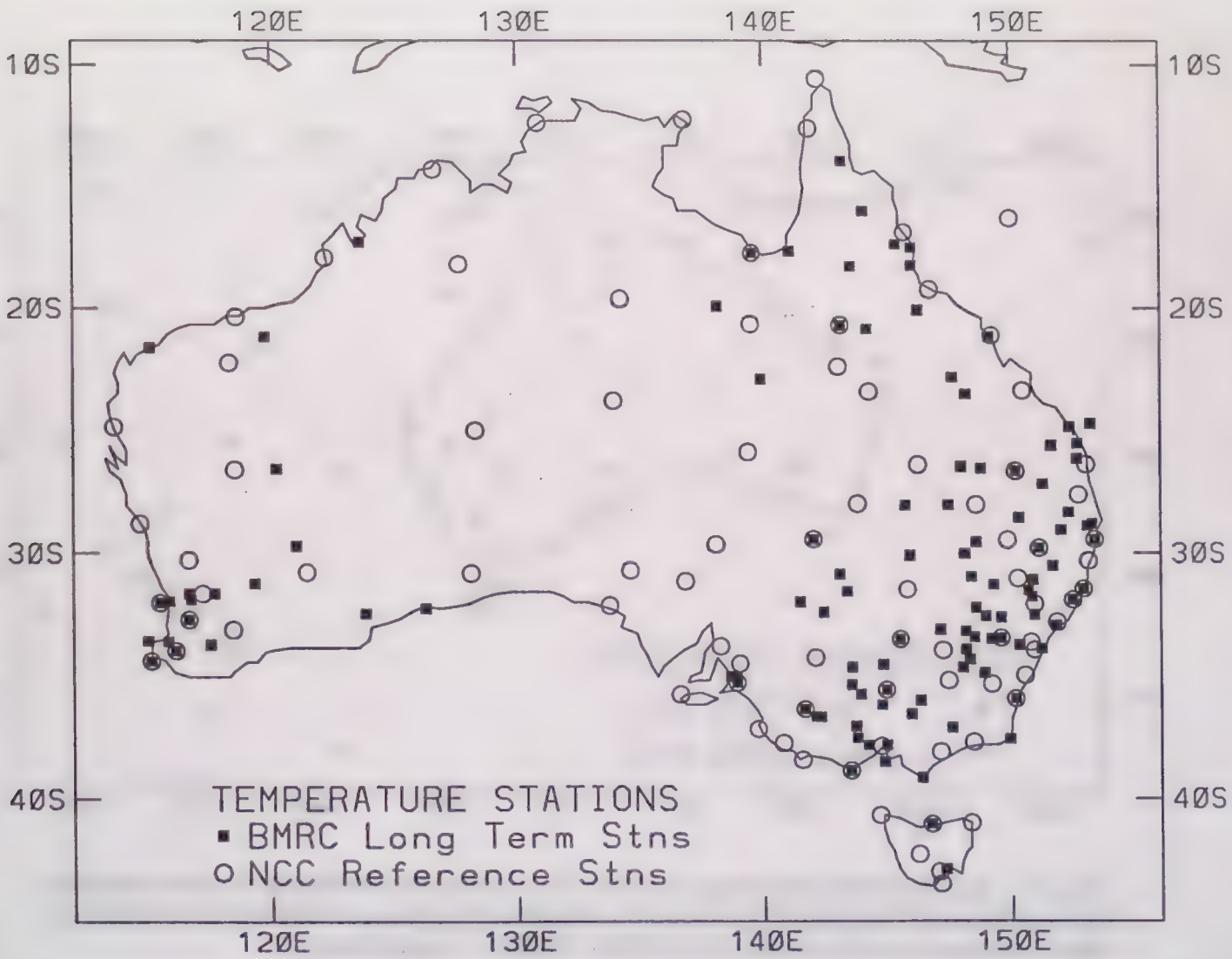

Figure 1. Spatial distributions of temperature stations in the BMRC long term data set (112 stations) and the NCC Reference Climate Network (85 stations).

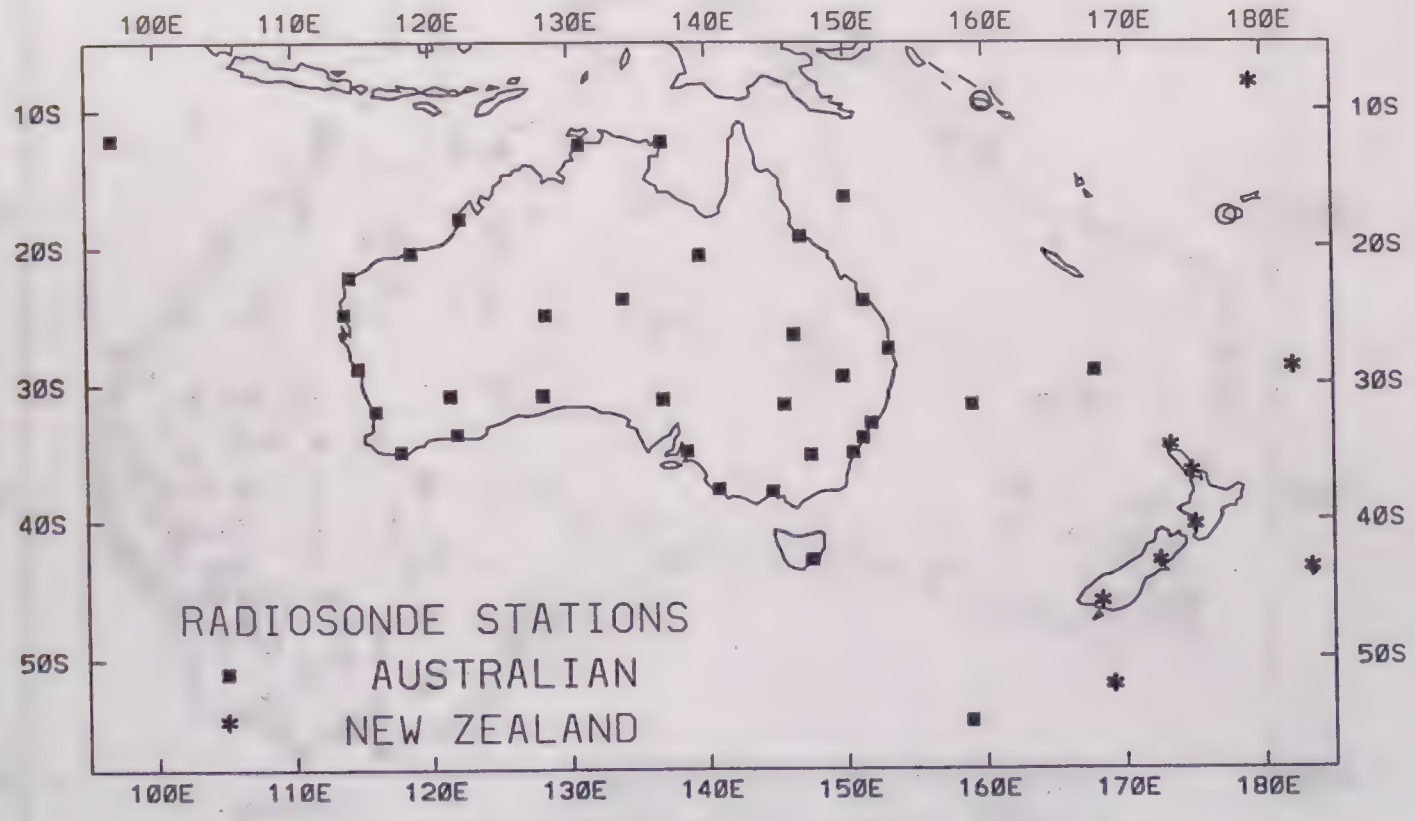

Figure 2. Spatial distribution of rawinsonde stations in the Australasian region operated by Australia and New Zealand, including Honiara and Fiji (open circles) for which data have been archived by Australia and New Zealand respectively.

Development of an Historical Canadian Climate Database (Temperature)

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Canadian Climate Centre

A number of researchers with the Canadian Climate Centre (CCC) were involved over the past several years in identifying long-term Canadian climate stations that are suitable for designation as Reference Climate Stations (RCS). This effort was carried out in support of the World Climate Data Program (WCDP) of the World Meteorological Organization (WMO). Over 700 temperature reporting stations were examined for length of record, missing data, spatial distribution, areal representation and homogeneity with nearby stations, and of these 254 were selected and recommended for designation as official Atmospheric Environment Service (AES) reference or baseline stations.

The CCC underwent extensive re-organization in the spring of 1991 with renewed and refocussed direction on climate change and related issues. The newly formed Climate Change Detection Division was tasked with extending the earlier work and creating an Historical Canadian Climate Database (HCCD) for use in climate change studies. Climate change investigations and analyses, state of the climate reporting, and contribution to international climate change activities were other new key responsibilities.

Initially the country was divided into 11 homogeneous climate divisions on the basis of earlier work by Hare and Thomas (1974) and on the basis of well defined ecological regions or ecozones as specified by the Office of the State of Environment. Temperature data were re-examined for length of record, homogeneity, etc. and a selection of 131 stations from the 254 RCS designates was made for creation of an historical temperature database. Monthly mean maximum and minimum temperatures were assessed separately, missing data gaps filled and data adjustments made where necessary to ensure compatibility with nearby stations. These were then combined into monthly mean temperatures and seasonal and annual means were computed. The HCCD contains these monthly, seasonal and annual series for maximum, minimum and mean temperature beginning where possible in 1895. The database also contains departures from the 1951-1980 reference averages; unadjusted original archive data, with and without missing data replacement; 1951-1980 normals and standard deviations; and a selection of pertinent station history information. The HCCD will be made available to climate change researchers on magnetic tapes and on PC diskettes.

Reference

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Results of Homogeneity Testing of Temperature Time Series

Some General Observations

1. Station history information (i.e., metadata) as it exists for much of the instrumental period is generally very inadequate.

2. Site photographs, sketches, and maps are invaluable in assessment of station site conditions over time.

3. The most frequent cause of detectable "step" inhomogeneities in monthly mean time series is "major" site relocations.

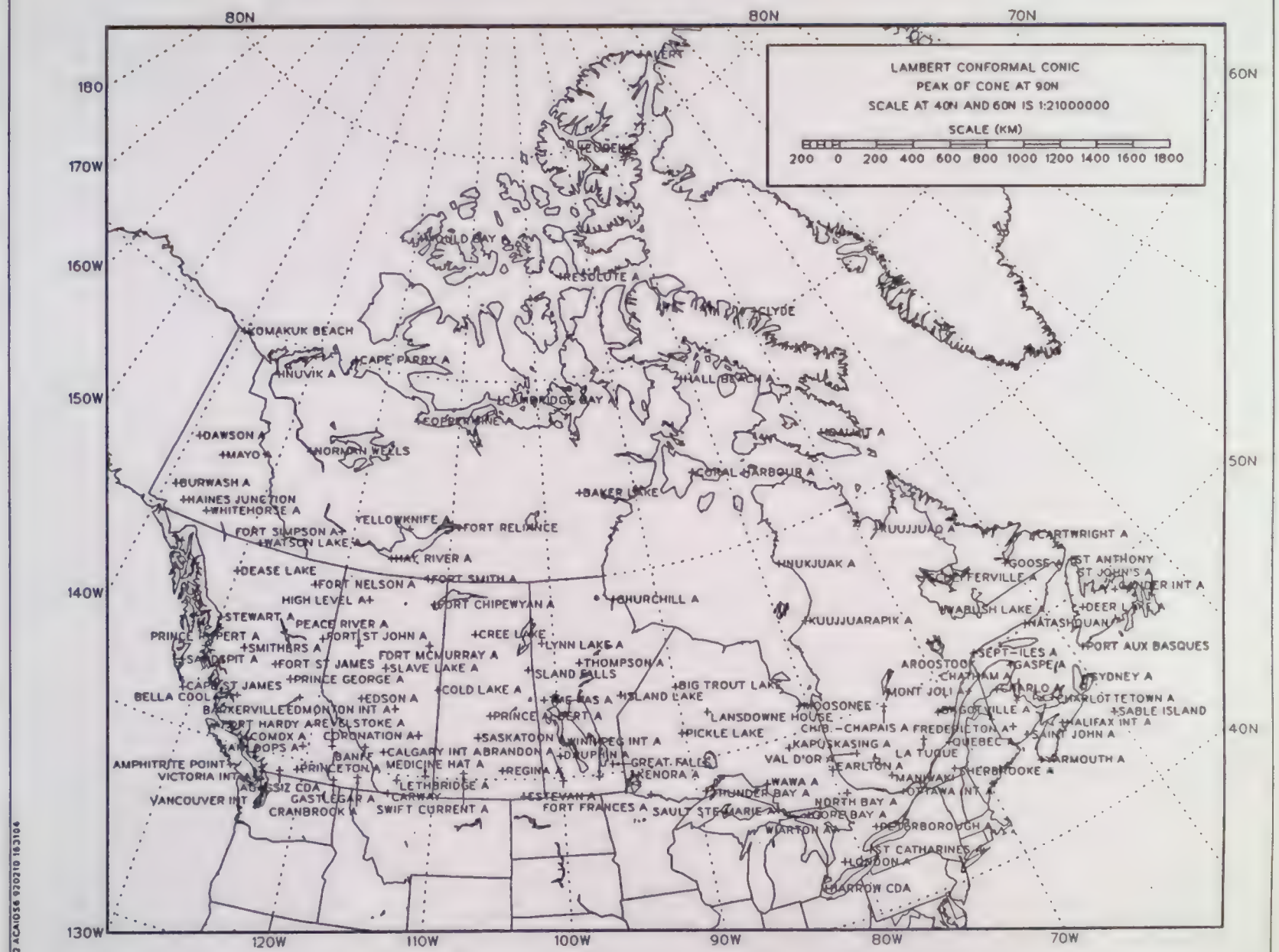
4. It is sometimes practical and feasible to "join" 2 stations series together to extend a record backward in time in spite of a distinct inhomogeneity created at the join.

5. Minor site changes, instrument changes, or poor observer practices often have no detectable effect on monthly time series.

6. It is often difficult to relate "changes" to physical causes because the information provided in the history files is often lacking in detail, lacking consistency, incomplete or irrelevant.

7. Minimum temperatures frequently appear to be more sensitive to individual site changes than do maximum temperatures.

CANADIAN CLIMATE STATIONS FOR HISTORICAL ANALYSIS



Environment Canada
Atmospheric Environment

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An evaluation of monthly mean MSU and ECMWF global atmospheric temperatures for monitoring climate

James W. Hurrell and Kevin E. Trenberth

National Center for Atmospheric Research*
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Monthly mean brightness temperature anomalies derived from channel 2 of the Microwave Sounding Units (MSUs) on board NOAA satellites over the past decade are examined and compared with both weighted and pressure level European Centre for Medium Range Weather Forecasts (ECMWF) monthly mean temperatures for the 96 months 1982-89. Details are reported in Hurrell and Trenberth (1992). Gridpoint correlations between the monthly mean MSU and weighted ECMWF anomalies are shown in Figure 1. Good agreement is evident over most of the globe with correlation coefficients over 0.9, but the agreement falls off over the tropics, the South Atlantic and high latitudes of the Southern Hemisphere. The lower correlations over some mountain regions may reflect a surface influence in the MSU data, plus the comparison differs in that a smaller depth of the atmosphere is represented. The same reasoning applies to much of Antarctica, where additionally the MSU signal may suffer from stratospheric contamination and problems exist in the ECMWF data. The ECMWF analyses agree best with the MSU data in regions of good radiosonde coverage, while lower correlations are found in regions where the analyses depend more heavily on satellite data. Systematic errors introduced into the analyses by the retrieval techniques applied to the radiance data largely explain this apparent contradiction. Additionally, changes to the analysis-forecast system at ECMWF over the decade appear as apparent changes in climate, and these discontinuities most strongly affect the tropics and are evident in regions of fewer observations.

To the extent that the weighted ECMWF data agree with the MSU brightness temperatures the vertical dependence of the MSU data can be examined. Correlations of the MSU data with ECMWF temperature anomalies at individual pressure levels (not shown) are highest at 300 mb over the globe, a level apparently least affected by the frequent changes and improvements at ECMWF. Over regions of good data coverage such as the Northern Hemisphere (NH) landmasses and Australia, the MSU anomalies correlate very highly with all levels of the troposphere up to 200 mb. Thus, the MSUs appear to be

* The National Center for Atmospheric Research is sponsored by the National Science Foundation.

an extremely useful tool for measuring global tropospheric temperature fluctuations on a monthly and longer time scale.

Problems in the ECMWF temperature record since 1982 are examined in some detail. Significant errors exist in the 1000 mb temperature field, especially over the oceans, throughout the entire study period. These problems are manifested as very poor anomaly correlations and spurious variance in comparisons of 1000 mb monthly temperatures with several SST analyses over the oceans. An example is the correlation with monthly anomalies from the Climate Analysis Center (CAC)SST analyses from 1982-89 (Fig. 2). Poor correlations are evident over all ocean regions, and values exceed 0.75 only in the tropical eastern Pacific where the climate signal is large. Such problems point to the lack of attention given to surface fields in the operational analyses of the atmosphere and, in particular, to the manner in which temperatures are not analyzed at ECMWF but rather are derived from virtual temperatures estimated from layer thicknesses of geopotential height.

The impact of changes to the ECMWF analysis-forecast system on tropical temperatures has been large and is illustrated in Fig. 3. In September 1982 the introduction of diabatic nonlinear normal mode initialization resulted in significant temperature increases in the tropical middle troposphere, especially at 500 mb. In May 1985 tropical temperatures at 700 mb (850 mb) increased (decreased) after the implementation of the T106 spectral model with major accompanying changes to physical parameterizations. Tropical temperatures near the tropopause decreased substantially after the May 1986 enhancement of the vertical resolution of the model from 16 to 19 levels with 3 new stratospheric levels. Such changes reduce the correlations evident in Fig. 1. Most importantly, however, comparisons with temperatures obtained from radiosonde stations in the tropics show that the ECMWF analyses have clearly improved with time, especially subsequent to May 1985 after which the 1000 to 200 mb tropical temperatures show much greater coherence.

It must be remembered that the ECMWF analysis system, like all operational systems, undergoes continual revision and development in order to fulfill its most important responsibility of providing improved forecasts. These revisions have led to substantial improvements in analysis and forecast accuracy over the past decade. The model-based global data set used in this and many other useful diagnostic studies of the general circulation is simply a by-product of the forecast mission. As such, for climate purposes the ECMWF analyses must be used intelligently with their shortcomings in mind. One must be cautious when trying to determine the natural variability of the climate system using these data, even on interannual time scales. It is in this light that there is a strong argument for the *reanalysis* of global data, and the results of this study support this need.

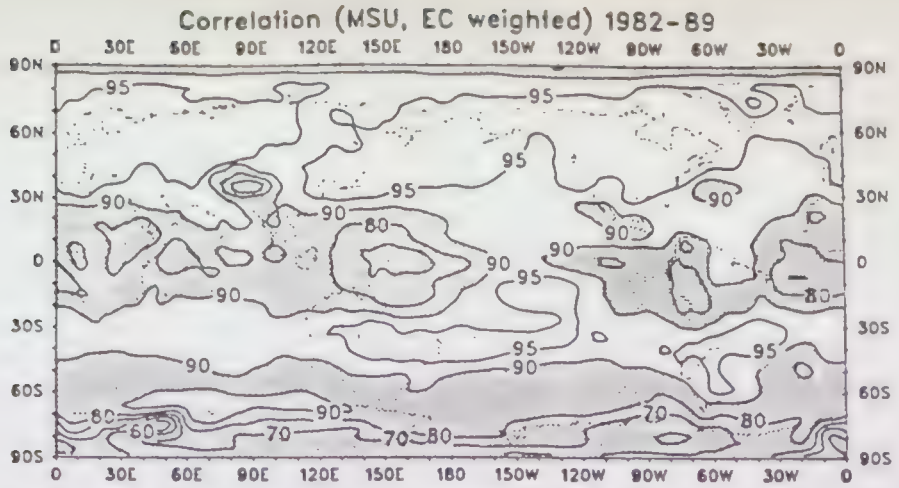

Fig. 1. Correlation over 96 months from 1982-89 of the MSU channel 2 and weighted ECMWF temperature anomalies. Values have been multiplied by 100 and the contour interval is 10, except the 95 contour is included. Values less than 90 are shaded.

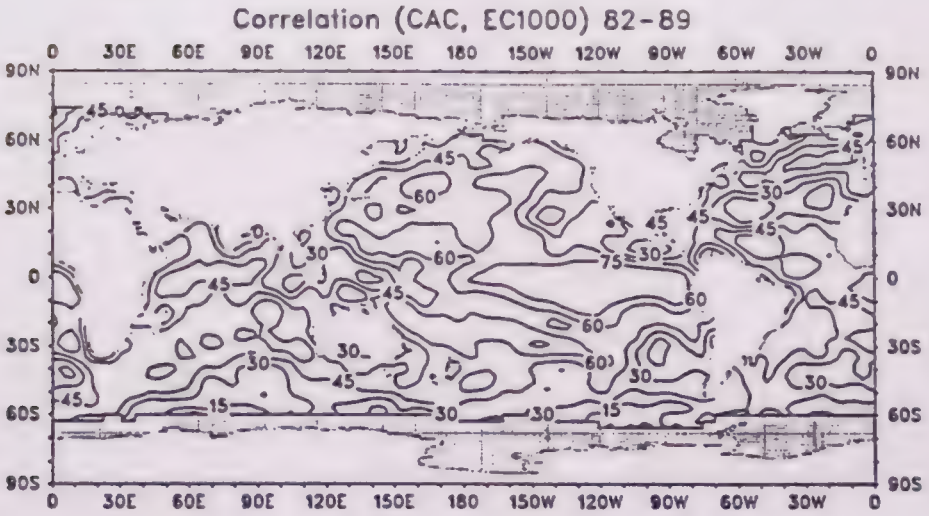

Fig. 2. Correlation over 96 months from 1982-89 for the CAC SST and ECMWF 1000 mb anomaly data. Values have been multiplied by 100 and the contour interval is 15.

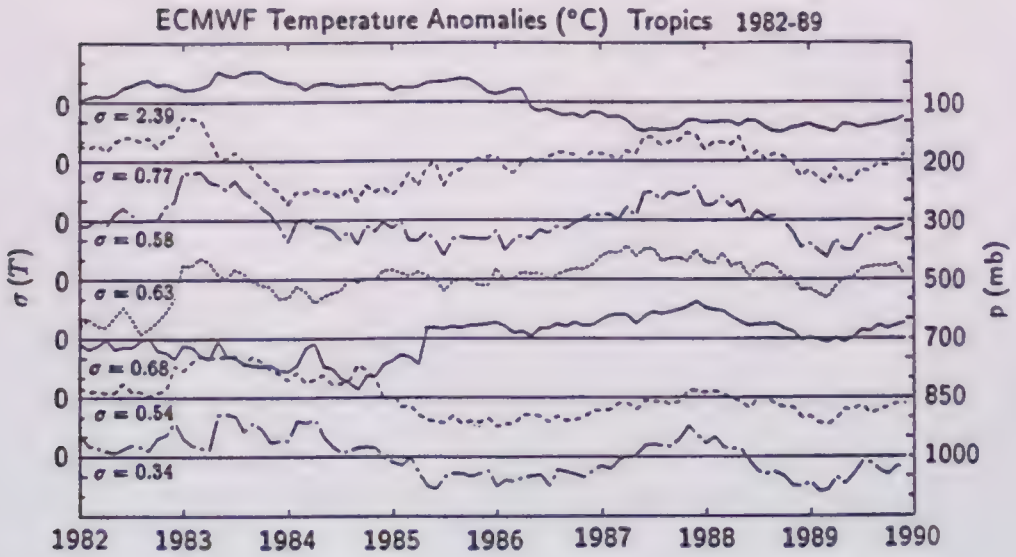

Fig. 3 Time series of ECMWF temperature anomalies at standard pressure levels area-averaged over the tropics. Each series has been normalized by its standard deviation and is offset by $\pm 3\sigma$. The standard deviation for each anomaly series is given just below the $\sigma = 0$ line.

Maximum and minimum temperature trends over Sudan, 1950-1987

by

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Recently produced datasets (Karl et al 1991) of maximum and minimum temperatures indicate that the observed warming trends over land areas may be primarily due to an increase of minimum temperatures with little change or even a cooling of maximum temperatures. The areas analysed cover about 25% of the global land area and comprise data from the United States, the Soviet Union and the People's Republic of China. Here an analysis is performed using similar data for 1950-87 for the largest country in Africa, the Sudan.

Data for five variables, for 15 stations, were extracted from national year books. The five variables were:- average maximum, average minimum, absolute maximum and absolute minimum monthly temperatures and mean monthly sunshine. The locations of the 15 sites are listed in Table 1. There is much missing data for sunshine and so far only data for the four temperature variables have been analysed. A national series for the four variables was produced by averaging anomalies for the 15 sites. Table 2 lists the amount of temperature change explained by a linear trend fit to each monthly series of the four variables. Seasonal time series for all four variables are given in Figure 1.

Warming over the 1950-87 period is evident in all variables, except for November to January in the maximum temperatures. For maximum temperatures there is a marked seasonal cycle with the greatest warming during July to September with the cooling in winter. There is little seasonal cycle in the degree of warming in minimum temperatures although warming is greatest in the transition seasons and is least in winter.

The warming in the maximum temperatures in the summer rainy season is consistent with the marked reductions in rainfall in this area while the cooling in winter is consistent with the increased numbers of dust and aerosol particles (from dust storm events) in winter and spring.

References

Karl, T.R. et. al. 1991: Global warming: evidence for asymmetric diurnal temperature change. Geophysical Research Letters, 18 2253-2256

Table 1: The 15 sites in the Sudan

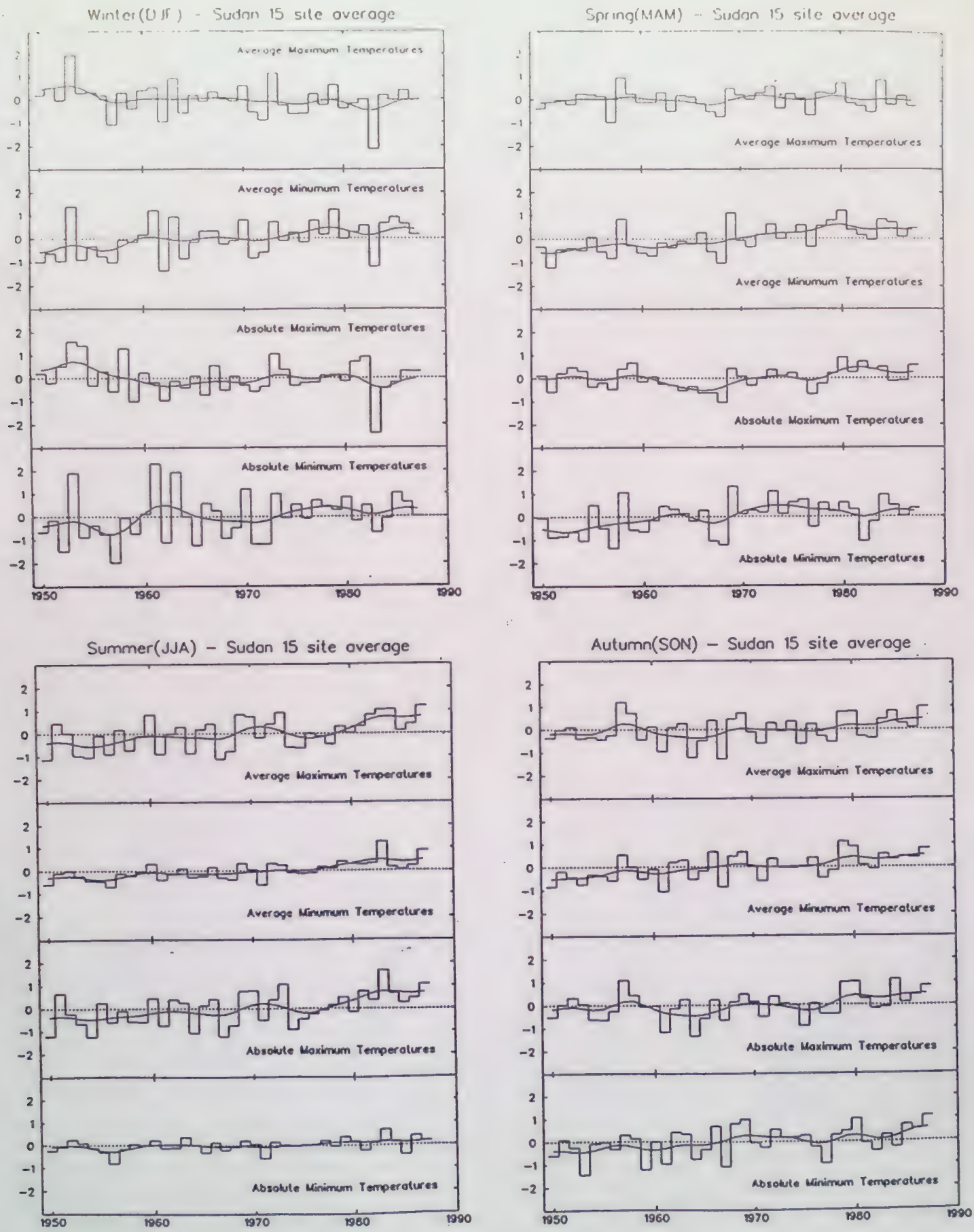
Station Name	Latitude (°N)	Longitude (°E)	Height (m)
Abu Hamed	19°32'	33°20'	315
Ed Dueim	13°59'	32°20'	380
El Fasher	13°38'	25°20'	730
El Obeid	13°10'	30°14'	570
Gedaref	14°02'	35°24'	600
Juba	4°52'	31°36'	460
Kadugli	11°00'	29°43'	500
Kassala	15°28'	36°24'	500
Khartoum	15°36'	32°33'	380
Malakal	9°33'	31°39'	390
Nyala	12°04'	24°53'	655
Port Sudan	10°35'	37°13'	5
Wadi Halfa	21°49'	31°21'	190
Wad Medani	14°23'	33°29'	405
Wau	7°42'	28°01'	435

Table 2: Temperature change explained by a linear trend fit to 1950-87 data (°C)

	Ave. Max.	Ave. Min.	Abs. Max.	Abs. Min.
January	-1.24*	0.60	-1.13*	1.15*
February	0.08	1.36*	0.15	1.15*
March	0.00	1.34*	0.72*	0.54
April	0.35	1.33*	0.33	1.63*
May	0.00	0.97*	0.12	0.67*
June	0.12	0.82*	0.63*	0.38*
July	1.20*	0.84*	0.74	0.35*
August	2.19*	0.90*	2.28*	0.27*
September	1.50*	1.30*	1.48*	1.14*
October	0.58*	1.50*	0.60*	1.30*
November	-0.54	0.24	-0.24	0.21
December	-0.53	0.95	-0.29	0.27
Year	0.31*	1.01*	0.45*	0.76*

*Significant at the 5% level

Figure 1: Seasonal temperature change for four temperature variables for the 15-site Sudanese average for 1950-87.



DAILY AND EXTREME TEMPERATURE DATA SETS WITHIN THE USSR

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Abstract

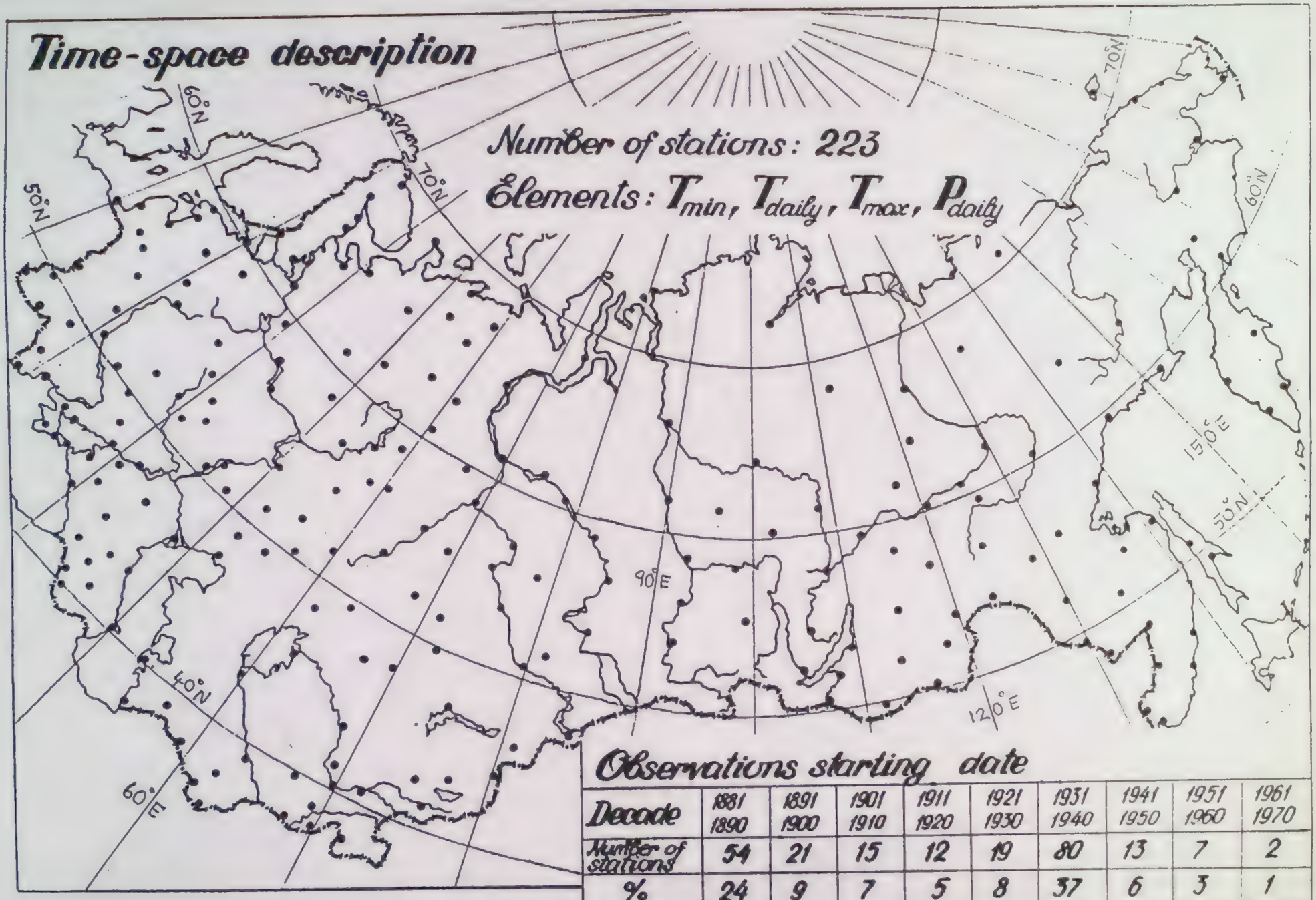
A set of daily values of the main meteorological elements - air temperatures and precipitation totals - was compiled in the USSR in 1988. It included data for 223 stations for the period from the beginning of record (but not earlier than 1874) to 1986 (Figure 1). Minimum and maximum air temperature values were also included. The set is intended, first of all, for the study of climate changes at the regional level. It is a part of the distributed global set of the daily values of the main meteorological elements, which is being created under the WMO program for baseline data set preparation for climate change detection.

The set was created on the basis of the archival data sets which are stored on magnetic tapes at RIHMI - WDC (Obninsk, Russia) and in the form of original observation tables. Special emphasis was laid on the problem of data completeness. Gaps, detected in the reference sets, were filled in using the tables of main meteorological observations. Special programs were developed to improve the data quality. In the course of data set compilation on magnetic tapes, data were subjected to primary quality control, which consisted of checks for climate limits. As a result, outliers were detected. The observation table values were assumed to be the correct ones and were used for introducing corrections. During the next steps of quality control the relationships between Tmin, Tmax and Tmean were checked as well as the correspondence between the monthly mean values, calculated for the given set, and the values available in the USSR Climate Handbook. Statistical analysis of temperature and precipitation series was carried out too. The main steps of data control have been completed and the set has been updated up to 1989.

However, errors in the relationship Tmin < Tmean < Tmax were revealed which are also found in the observation tables. A control procedure is currently being developed, which is based on the use of both the information about daily values of other meteorological elements, weather data included, and 3-hourly observation data. Using such a procedure, it will become possible in a number of cases to specify the reason for the violation of the relationship Tmin <Tmean <Tmax and to recover the true values. The same procedure is also used to verify the correctness of the individual extreme values in the series of daily precipitation and temperature values, as well as to reveal the erroneous values in the observation tables.

Data set homogeneity study is given special attention. A special station history data set was prepared, which contains information about the recorded changes in the station location, the station elevation, the observation times, the instruments etc. On the basis of this information, heterogeneities can be revealed in the series of the extreme temperature values. Nevertheless, special methods of eliminating heterogeneity from the daily data series still need to be developed.

At present, the most promising use of the data set is the study of asymmetry in minimum and maximum temperature change, which has been recently detected (Karl et al: Global warming: evidence for asymmetric diurnal temperature change. Geophys.Rev.Lett., 18, 2253-2256 (1991)).



Observations starting date

Decade	1881 1890	1891 1900	1901 1910	1911 1920	1921 1930	1931 1940	1941 1950	1951 1960	1961 1970
Number of stations	54	21	15	12	19	80	13	7	2
%	24	9	7	5	8	37	6	3	1

FREE ATMOSPHERE TEMPERATURE VARIATIONS: A MULTIDIMENSIONAL MODEL BASED ON HISTORICAL RADIOSONDE DATA

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ABSTRACT

The quality controlled (QC'd) observational radiosonde data for the period 1961-1975 were used for 834 upper-air stations over the globe. The time series of monthly mean temperature for isobaric levels were obtained, and the objective analysis of monthly means enabled us to obtain gridded monthly temperature data.

The further generalization of gridded data was as follows:

a) vertical averaging for various atmospheric layers (mass-weighting);
b) zonal averaging;
c) estimation of anomalies;
d) horizontal averaging of anomalies for latitudinal belts;
e) temporal generalization for seasons.

We intercompared zonal seasonal temperature anomaly time series thus obtained with similar time series obtained by A.Oort and by J.Angell.

The multidimensional characteristics of temperature anomalies for various zones and layers of the global atmosphere were studied using the principal components (PCs). Eighteen variables were introduced as values of seasonal anomalies of mass-weighted temperature for three atmospheric layers: lower troposphere (850-500 hPa), upper troposphere (500-200 hPa), lower stratosphere (200-10 hPa), - and for each of the six 30-degree latitudinal zones of the globe.

The eigenvectors, corresponding to PC1, PC2, PC3 and PC4 are presented (Table 1) and discussed.

The PCs have been constructed using temperature anomaly series for natural seasonal sequence (Fig.1). Four subsets of the PC values, corresponding to each of the four seasons, were separately observed and discussed.

It was noted that the following two periods may be identified:

- winter 1960/61 - spring 1968,
- summer 1968 - fall 1975,

which are linearly dividable in PC1 and PC2 space.

The specific differences between temperature characteristics of the Northern Hemisphere winter season and those of other seasons were detected due to the multidimensional principal component analysis.

Table 1

Values of the First Four Eigenvectors of Lower (850-500 hPa) and Upper (500-200 hPa) Troposphere and Lower Stratosphere (200-10 hPa) Average Weighted Temperature Seasonal Anomaly Correlation Matrices for Six Latitudinal Zones of the Globe (RIHMI-WDC data, number of seasons - 60)

λ- total variance fraction accounted for by the corresponding principal component

LT - lower troposphere
UT - upper troposphere
SR - lower stratosphere

Eigenvector number	λ	Layer	Latitudinal zone					
			90 S - 60 S	60 S - 30 S	30 S - 0	0 - 30 N	30 N - 60 N	60 N - 90 N
1	0,253	SR	0,001	0,009	-0,189	-0,295	-0,278	0,147
		UT	-0,312	-0,056	0,409	0,361	-0,029	0,083
		LT	-0,316	-0,001	0,405	0,322	-0,065	0,008
2	0,165	SR	-0,024	-0,012	0,059	0,140	0,050	0,157
		UT	0,242	0,183	0,045	0,273	0,447	0,382
		LT	0,242	0,217	0,030	0,265	0,459	0,215
3	0,128	SR	-0,098	0,461	0,400	0,182	0,219	0,016
		UT	0,100	-0,374	0,105	0,176	-0,066	-0,041
		LT	0,193	-0,452	0,151	0,260	-0,080	-0,038
4	0,108	SR	0,484	0,290	-0,193	-0,360	-0,293	0,369
		UT	0,307	-0,021	-0,139	-0,092	-0,050	0,216
		LT	0,196	-0,201	-0,114	-0,033	-0,053	-0,153

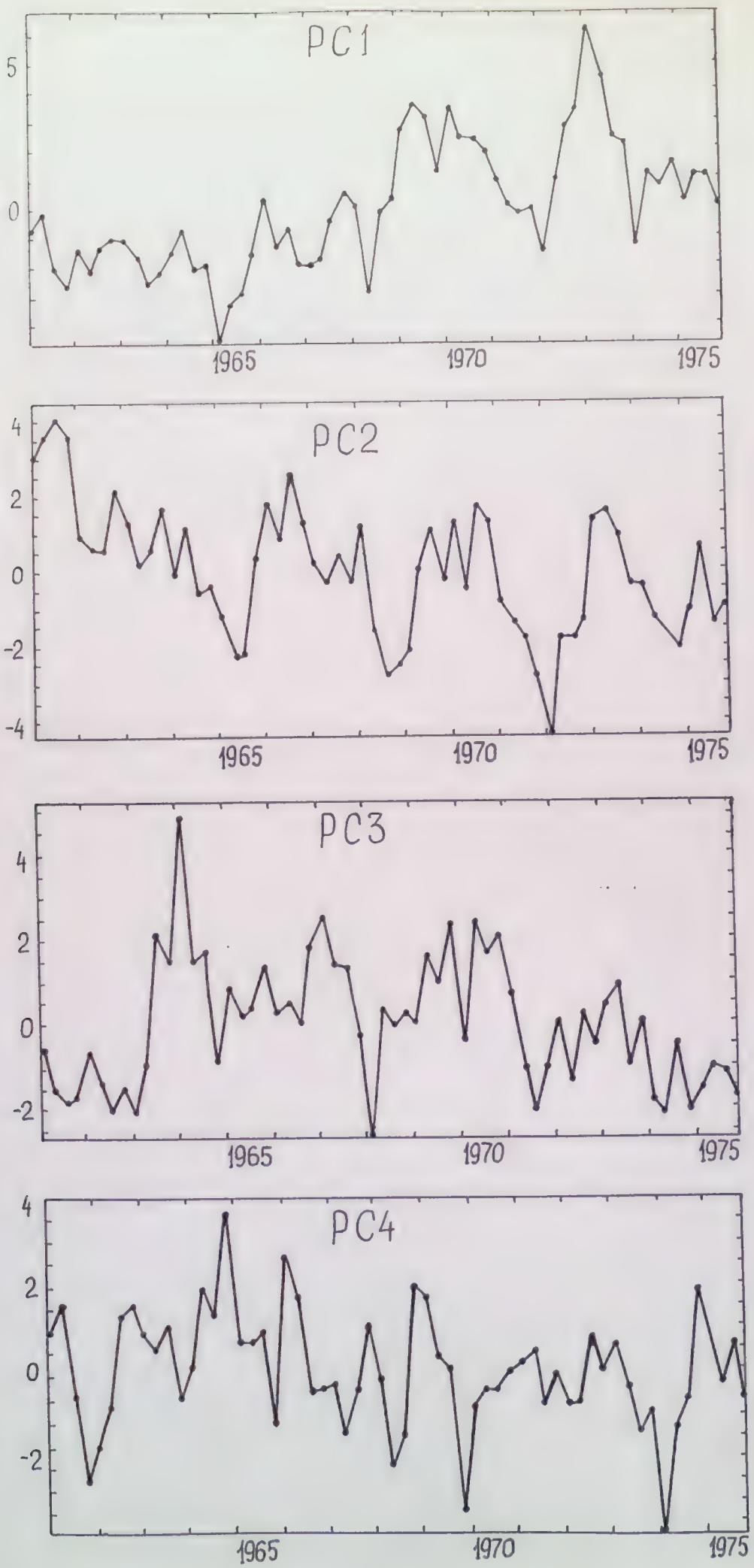
PC1
5
0
1965
1970
1975
PC2
4
2
0
-2
-4
1965
1970
1975
PC3
4
2
0
-2
1965
1970
1975
PC4
4
2
0
-2
1965
1970
1975

Figure 1.

NCAR Datasets with Daily Maximum and Minimum Temperatures

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For a number of years the National Center for Atmospheric Research (NCAR) has been acquiring and storing *daily* station data from around the globe (Table 1). These data sets most commonly contain daily minimum and maximum temperatures (T_{min} and T_{max}, respectively) and precipitation. Other variables are reported less often: these include sea level pressure, wind speed and direction, relative humidity, cloud type, etc. These daily data are currently being used for agricultural studies, climate research, and to validate climate models. For example, the difference between T_{max} and T_{min} gives an indication if the models are correctly simulating the diurnal cycle.

Some of the datasets span more than 75 years (e.g., DS510 and DS516) while others contain data for a fairly short time period (e.g., DS469). The datasets contain information from several different continents. However, only DS512 spans the entire globe and is temporally current. That dataset is acquired from the Climate Analysis Center (CAC) and is described in detail by Miskus et al (1988). Briefly, data are obtained from the Global Telecommunication System, quality checked, and archived. On any given day, T_{min}, T_{max}, precipitation, and other variables from more than 5000 stations around the globe (figure 1) are available. Currently, the data available at NCAR span 1979 through June 1989. The CAC is updating the data through 1991. In addition, it is possible that the CAC will add 1977 and 1978 daily data. NCAR archives this data in both synoptic *and* time series order by station.

It is possible that DS512 could be significantly expanded by using daily data spanning 1967-76 from DS463 and data from DS467 which contains data nominally starting in 1901 but with the vast majority starting in about 1940 (figure 2). A project that involves several centers including NCAR is now under formation. It's main purpose is to recover data for missing periods and to extend the daily data archive back in time.

TABLE 1
NCAR Datasets containing T_{min} and T_{max}

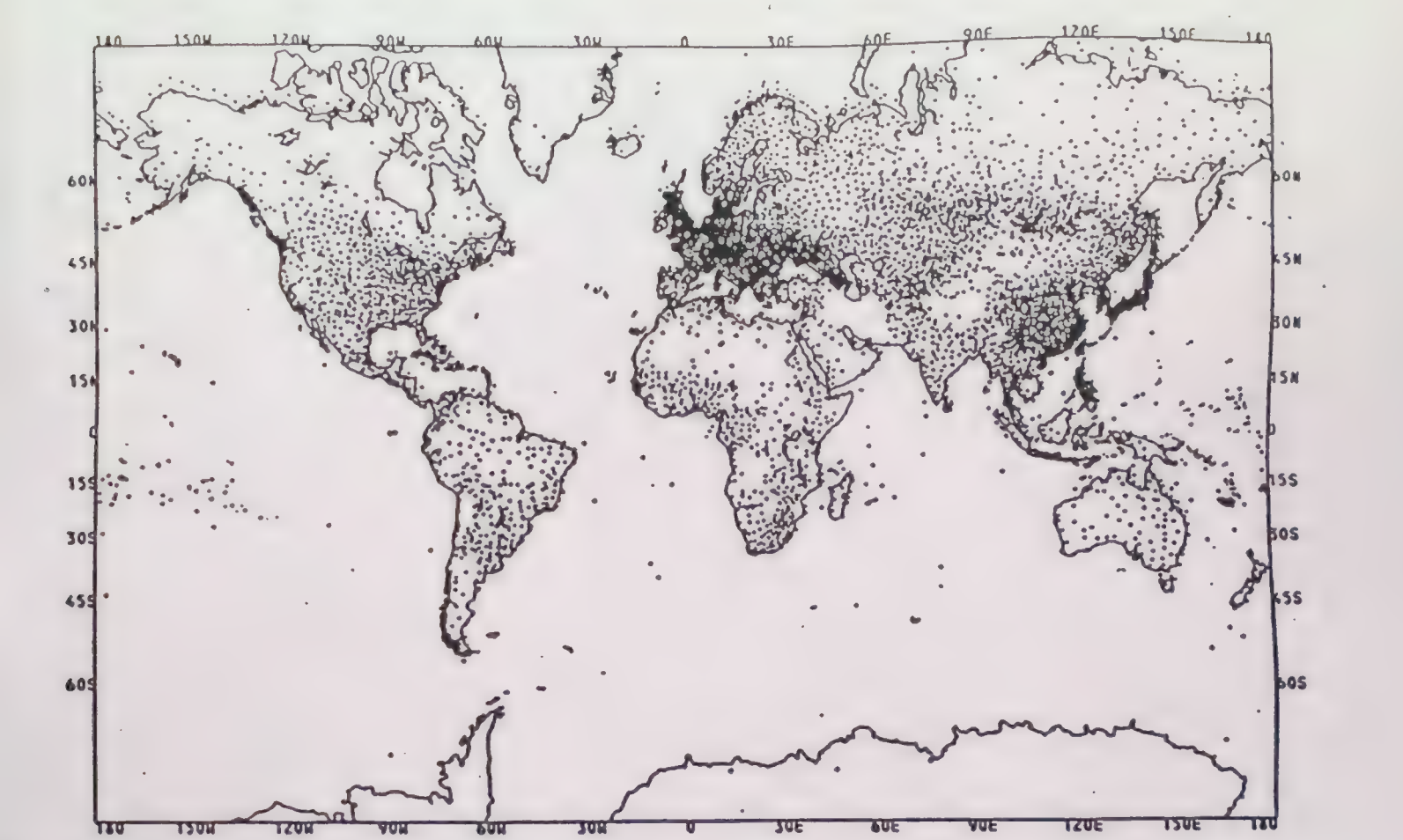
NCAR ID	AREA	NO. STA.	PERIOD	TYPE	ORDER	VOL
DS463	Global	7,500	1967-80	D	S	L
DS467	Global	7-10,000	1899-72	D	T	L
DS469	Canada	95	1963–72	D	T	S
DS483	Malaysia	111	1951–85	D	T	S
	Thailand	52	1951–85	D	T	S
DS508	USA	137	1881–1985	D	TS	S
DS510	USA	11,000	1888–1990	D	T	L
	Pacific Is. Caribbean					
DS512	Global	7500	1979–6/89	MD	TS	M
DS516	Canada	780	1874–1989	D	T	L
DS518	Japan	100+	1951–89	D	T	S
DS522	USA	372	1888–1976	D	T	S
	Canada	127	1874–1979	D	T	
DS523	Australia	10,000	1939–82	D	T	M
DS565	USA	1200	1880–1987	M	T	M
DS582	Antarctica	47	1980–89	MD	T	S
DS	Switzerland	9	1901–89	D	T	S

Table 1 description: NCAR ID indicates NCAR's internal dataset identifier; AREA indicates the primary geographical location of the data; NO. STA. indicates the approximate number of stations; PERIOD specifies the time spanned by the data set; Type means D for daily and M for monthly; ORDER indicates the manner of archiving where T means time series order and S means synoptic order; VOL indicates whether the data set is small (S), medium (M) or large (L) where S means the data may be contained on one 6250 tape; M means 2-10 tapes and L means more than 10 tapes. Note: The data from Switzerland is not yet ready for distribution.

References

Miskus, D., J.D. Laver, and F.G. Finger, 1988: The Climate Analysis Center's Interactive Climate Assessment Data Base, Fourth International Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology, Jan. 31 - Feb. 5, 1988, Anaheim CA.

Figure 1: A sample of the distribution of stations on any given day in DS512.



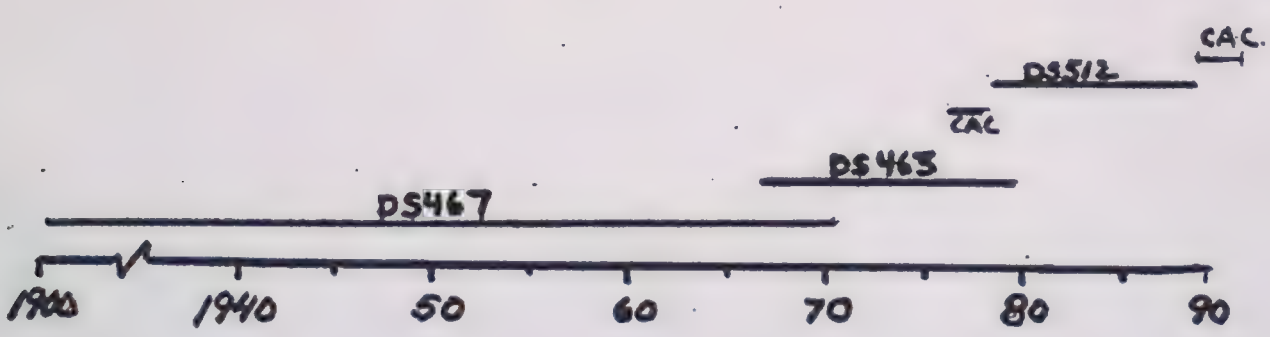


Figure 2: Datasets archived at NCAR which may be used to extend DS512 back to 1901 in some instances.

Differences between Surface and Tropospheric Global Temperatures, 1979-1990

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Although the several global temperature datasets that have been developed are broadly consistent with each other, analysis of the differences among them may indicate how best to use the various observations and data treatments in a complementary way to advance our understanding of climate change processes. This study compares three global temperature compilations: that developed at the Goddard Institute for Space Studies (GISS) for land surface air temperatures (Hansen and Lebedeff 1987); the combined land and marine temperature series prepared by the Climate Research Unit (CRU) at the University of East Anglia (Jones et al. 1991); and the lower troposphere temperatures derived from satellite Microwave Sounding Unit (MSU) observations, as outlined by Spencer and Christy (1992).

Monthly temperature departures from the 1982-1990 average were compared for 2.5 degree grid boxes, over the common period of record, beginning in 1979. Global annual averages for the three datasets and for the surface-troposphere differences (Figure 1) reveal the following:

1. The standard deviations of both the surface and tropospheric global annual anomalies (Figure 1A) and their differences (Figures 1B-C) are similar and range from about 0.1 to 0.15 degree C. This variability is much larger than the effect on the surface-troposphere temperature difference of the incomplete and variable coverage of the surface datasets relative to the full global coverage of the satellite observations (compare the solid and dashed lines in Figures 1B and C). This pattern suggests that differences in sampling and coverage explain only a small part of the differences between the surface and satellite observations.

2. Much of the difference between the surface and satellite observations may have a physical basis. For example, the surface datasets show less warming relative to the troposphere during the warm episodes of the 1979-1990 period.[1] During warm episodes, transfer of heat from a warm surface through vertical advection/convection could contribute to a larger atmospheric warming relative to surface warming.

3. The surface data show an upward trend relative to the MSU of about 0.15 degree C/decade. This trend may depend on the timing of warm and cool episodes during the 12-year record and may in part be an artifact of a slight bias towards warm episodes, and, therefore, greater tropospheric warming, in the earlier part of the record.

Comparison of the zonal monthly temperatures for the three data sets (Figure 2) gives a more detailed picture of the features illustrated in Figure 1:

1. The effect of the difference in coverage between the surface and satellite datasets is small--even when examined at the finer zonal/monthly resolution. (Compare Figures 2D and E, the zonal averages of the surface-satellite temperature differences for common grid cells in each 2.5 degree latitude zone, with Figures 2G and H, the differences between the surface and satellite zonal averages, where the two zonal averages are computed separately using all grid cells in the zone with non-missing temperatures.)[2]

2. Both surface and tropospheric temperature changes are characterized by high frequency and large magnitude at high latitudes and low frequency and smaller magnitude at low latitudes (Figures 2A-C). This latitudinal difference may in part explain previous findings of reduced correlations between surface and tropospheric temperature in the tropics. That the surface-troposphere temperature differences (Figures 2D,E,G,H) are also more variable and larger at high latitudes is very likely a real physical difference: relatively stable atmospheric conditions at high latitudes, especially in winter, can keep surface anomalies more vertically confined than is the case in the tropics. An abrupt change in variability occurs in all three data sets at about 60 degrees S (Figures 2A-C). Could this change be related to the transition from a strong circumpolar current to Antarctica?

3. The 1979-1980 tropical warm feature, although diffuse and weak, appears to be real and is strongest in the MSU dataset. The occurrence of this warm feature at the beginning of the 12-year record may contribute to the MSU data's smaller decadal trend relative to the surface data.

4. The warming associated with the 1983 El Nino appears to have been confined to low latitudes, possibly as a result of the countervailing cooling effect of aerosols from the 1982 eruption of El Chichon.

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[1] Although there was no El Nino in 1979 and 1980, sea surface temperatures in the tropical Pacific were warmer than usual.

[2] The two vertical lines in these plots denote two missing months of MSU data, April and August 1981.

(This apparent suppression of the 1983 El Nino coincides, as shown in Figures 1B and C, with a reduced annual global surface-satellite temperature difference relative to the other warm episodes.) In contrast, the 1987-88 El Nino gives the impression of having propagated warmth to higher latitudes in a sideways "V" pattern--a pattern that is also faintly echoed in the 1979-1980 warm feature (Figures 2A-C).

5. The GISS temperatures tend to be slightly warmer than the CRU temperatures during warm episodes (Figures 2F and I).

In summary, this preliminary comparison of three global temperature datasets suggests that, while all three capture much of the same variation in temperature, there are systematic differences among the three datasets which may be in large part explained by the fact that the three datasets are observing related, but different, parts of the climate system.

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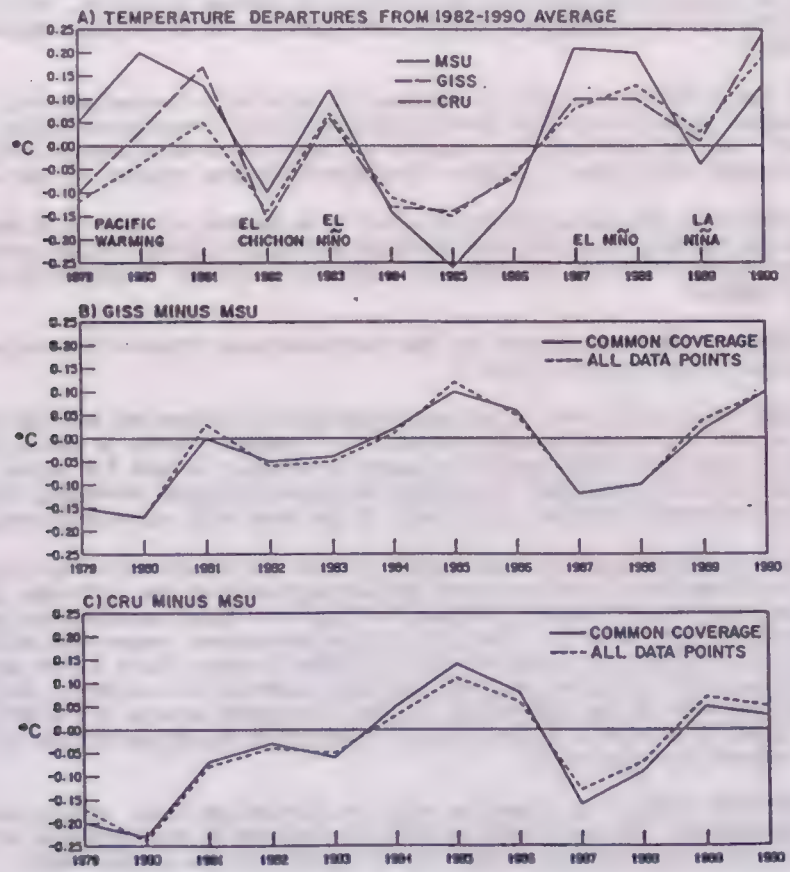

Fig. 1. Comparison of surface (GISS and CRU) and lower troposphere (MSU) global annual temperatures. A) shows the temperature departures of the three datasets from the 1982-1990 average. B) and C) show the values for surface temperature minus troposphere temperature. The global annual average temperature differences in B) and C) are computed for only those grid points with non-missing monthly temperatures in both datasets (solid line) and for all data points (dashed line). Hence the difference between the solid and dashed lines is the temperature difference which results from the difference in the space-time (grid cell and month) coverage of the two datasets. Major interannual warm and cool episodes are indicated in A).

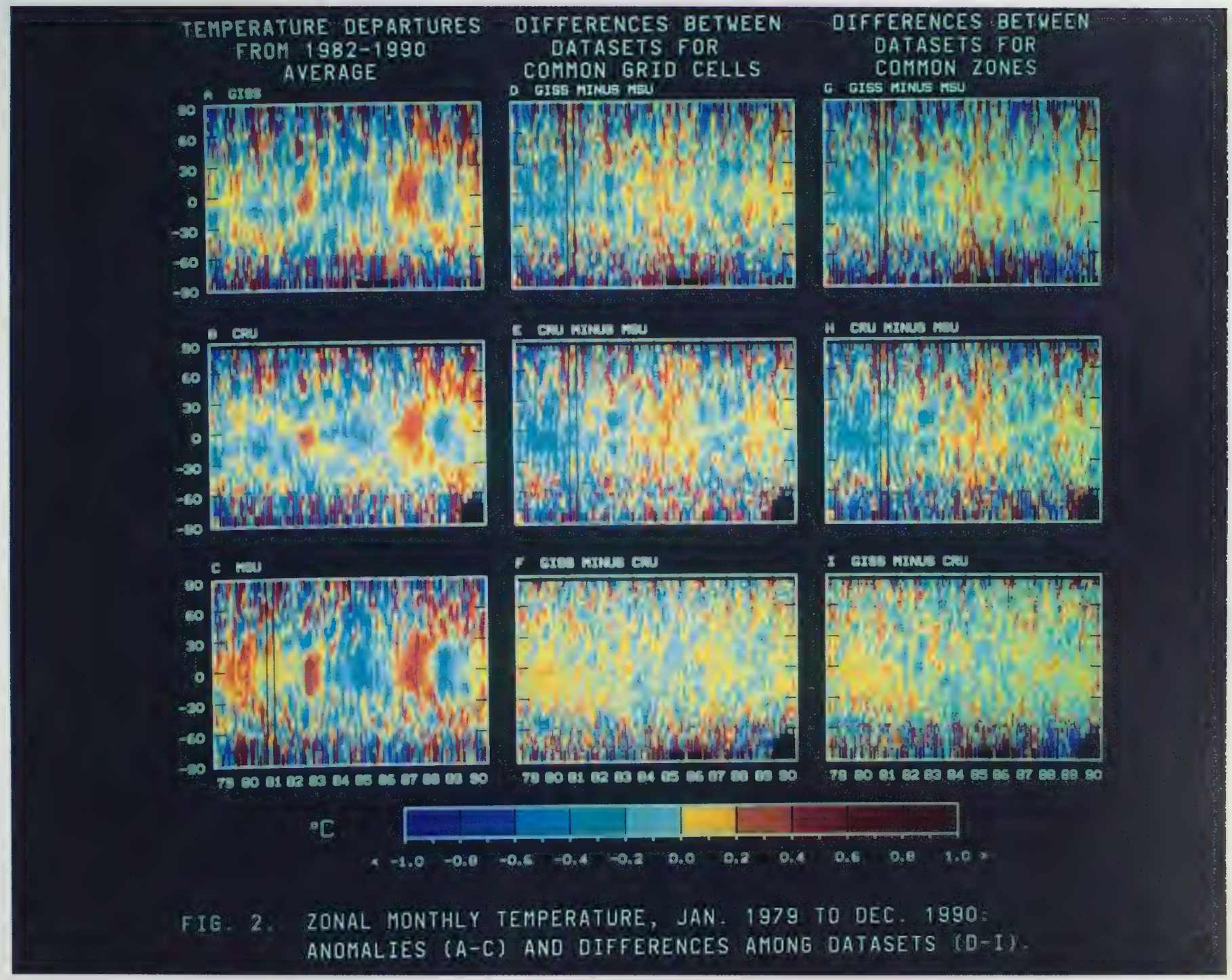

FIG. 2. ZONAL MONTHLY TEMPERATURE, JAN. 1979 TO DEC. 1990: ANOMALIES (A-C) AND DIFFERENCES AMONG DATASETS (D-I).

Comparison of the Variabilities of Sea Surface Temperature and Free Air Temperature from GOSTA and MSU Data

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Data sources used for the comparison were, for sea surface temperature (SST), the Global Ocean Surface Temperature Atlas (GOSTA) (Bottomley et al., 1990) and for free air temperature, measurements by microwave sounding units (MSU) on satellites as described by Spencer et al. (1990).

Conventionally defined standard deviations are compared in Figure 1; they are evaluated from data for all months taken with respect to the appropriate long term monthly means for the 1979-1988 period, thus they represent the standard deviation of what are often termed anomalies. Largest values for SST are in the tropical eastern Pacific and extend westwards in a tongue from the continent in the region known to be controlled by upwelling. By contrast the smallest values are in the tropical west Pacific, a region thought to be limited to a temperature maximum of about 30°C by evaporation, and which is well known to vary little about this temperature, and in the tropical and subtropical Atlantic. The MSU data apply to a weighted tropospheric layer with maximum weight near 70 kPa. Largest values are in the tropical belt with maxima just south of the equator and a minimum over the tropical eastern Pacific where SST variabilities are a maximum. Smallest values are in latitude belts centered at about 30°N and 40°S with a further increase polewards. Note that SST variabilities show large east-west variations in the tropics while the MSU patterns are nearly uniform with longitude but show large variations with latitude.

The spatial coherence is defined as the areal average of the correlation coefficients computed from time series of monthly anomalies for a central point and those for separate grids surrounding the point out to a latitude longitude span of 15° in each direction. The fields are shown in Figure 2 and bear some similarity to the standard deviation patterns. MSU shows high values in the tropical belt and large values also at high latitudes. The main feature of the SST maps is the maximum in the tropical eastern Pacific. Note that the chaotic patterns north of 70°N and south of 50°S are artifacts of the poor data coverage in these regions.

A third measure of variability presented at the workshop was an estimate of the number of independent samples out of the total of 120 monthly values for the 10 year period. Low values correspond to high persistence. For SST, lowest values (about 30) occurred in the tropical east Pacific and highest values (about 80) in the tropical west Pacific. For MSU the entire tropics was in the 20-30 range denoting strong persistence while the middle latitudes showed values up to 100 except for patches over the Gulf Stream and Kuroshio. Measures of related variability between the two fields were also illustrated at the workshop as described by Newell and Wu (1992).

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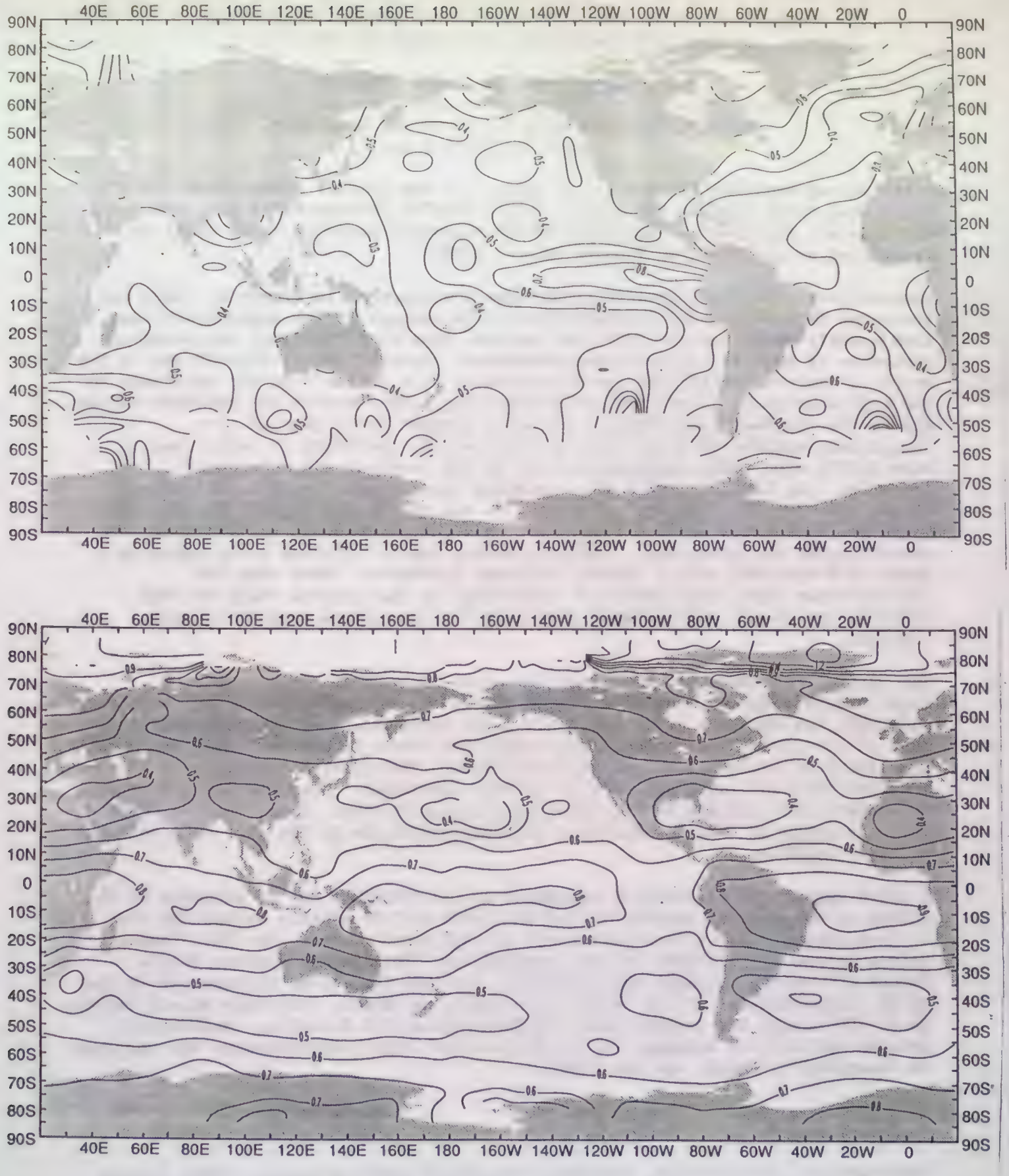

Figure 1. Standard deviation of monthly temperature anomalies, 1979-88, °C
Top: SST (data from Bottomley et al., 1990).
Bottom: MSU for the troposphere (data from Spencer et al., 1990).

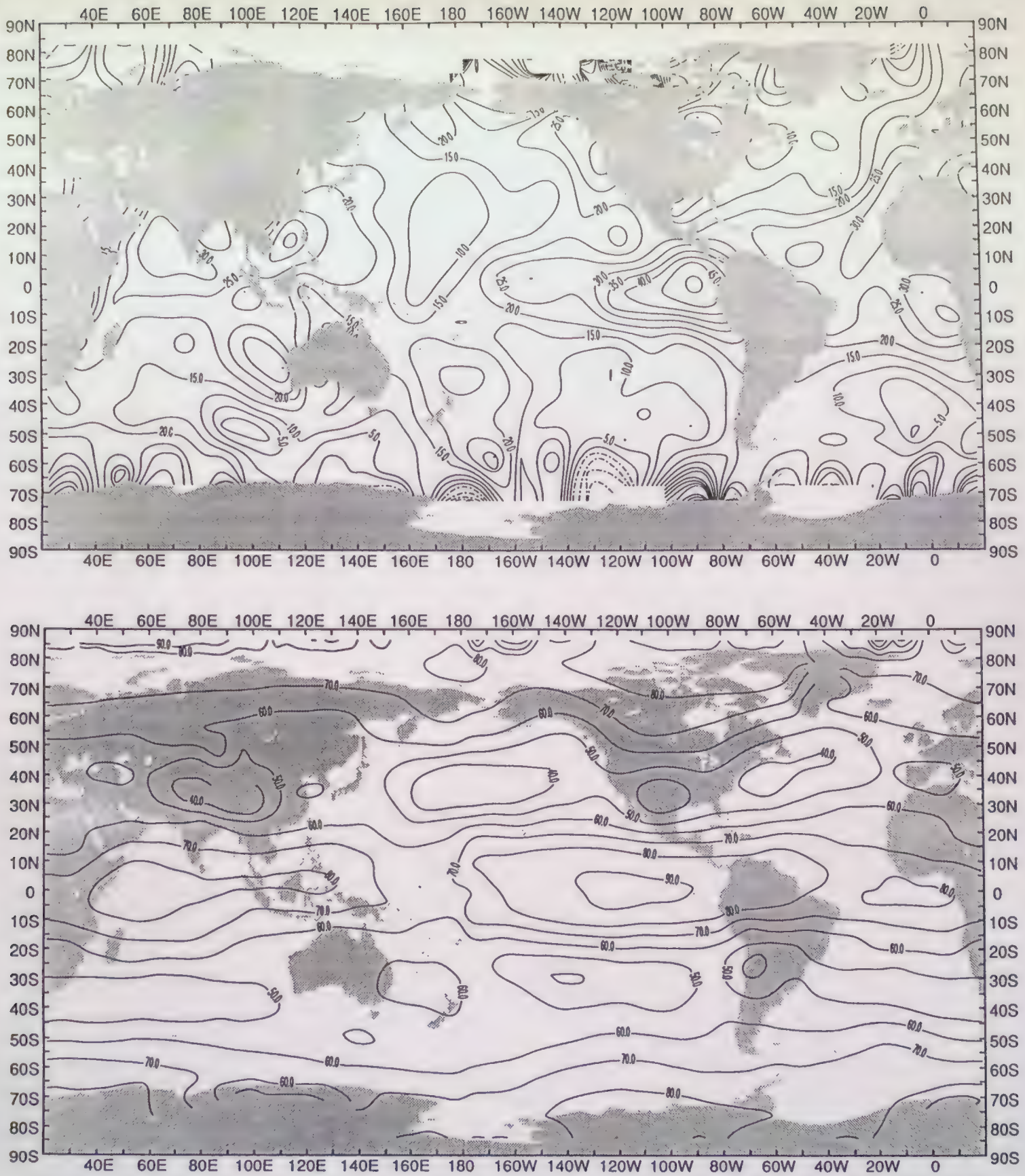

Figure 2. Spatial coherence of monthly temperature anomalies, 1979-88, %.
Top: SST (data from Bottomley et al., 1990).
Bottom: MSU for the troposphere (data from Spencer et al., 1990).

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4. ACRONYMS

COADS	Comprehensive Ocean-Atmosphere Data Set
ECMWF	European Centre for Medium-Range Weather Forecasts
ERL	Environmental Research Laboratories
GISS	Goddard Institute for Space Studies
GOSTA	Global Ocean Surface Temperature Atlas (Bottomley et al, 1990: see references in abstract of Z-X Wu and R E Newell)
GPCP	Global Precipitation Climatology Project
MSU	Microwave Sounding Unit
NCAR	National Center for Atmospheric Research
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
RIHMI	Research Institute of HydroMeteorological Information
TRMM	Tropical Rainfall Measurement Mission
UEA	University of East Anglia (Norwich, UK)
WDC	World Data Centre
WGNE	Working Group on Numerical Experimentation
WMO	World Meteorological Organization

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CRTN 30	Jun 1992	International Temperature Workshop, Boulder, Colorado, USA, 16 January 1992 Edited by D E Parker